Jurnal Teknik Industri
Vol. 20, No. 1, February 2019, pp. 34-44

The Measurement of Physical Workload and Mental Workload Level of Medical Personnel

Dian Palupi Restuputri *, Anindia Karunia Pangesti, Annisa Kesy Garside
Department of Industrial Engineering, University of Muhammadiyah Malang, Indonesia
Jl. Raya Tlogomas No.246 Malang, Jawa Timur, Indonesia Phone: +62 341 464 318
* Corresponding author: restuputri@umm.ac.id

ARTICLE INFO

Article history
Received December 23, 2018
Revised February 20, 2019
Accepted February 25, 2019
Available Online February 28, 2019

Keywords
Physical workload
Mental workload
NASA-TLX
Heart rate
Medical personnel

ABSTRACT

As the primary health reference center, a hospital must provide excellent quality services to each patient. The impact of the extreme physical and mental workload causes negligence in activities. It affects the quality of services provided by medical personnel. This study investigated the level of mental workload and physical workload in medical staff in a hospital. This study was conducted at 15 units in the hospital. The mental workload was assessed using the NASA-TLX Questionnaire. The physical workload analysis was carried out with the Heart Rate reserve percentage of medical personnel. This study shows that the mental workload of nurses in the Intensive Care Unit (ICU) is higher than the other units. Whereas the calculation of physical load using % HR reserve turns out the nurse's head in-unit class 1 has the highest value than the other unit. The statistical analysis showed a difference in the general practitioner workload toward the Head of Nursing.

1. Introduction

In ergonomics, the workload must be appropriate physical abilities, cognitive abilities, as well as limitations [1]. The workload is divided into two categories. The first is the physical workload. It occurs if there different workload toward the physical workers' ability. The second is the mental workload. It is the difference between mental workload and psychic abilities workers. The workload related to worker fatigue. Several activities that affect fatigue included working too hard, the wrong posture, and unacceptable conditions. The workload is influenced by factors external and internal. Physiologically, mental activity is a type of work with low caloric. However, mental activity is substantial than physical activity as it involves the brain [1]. The mental activity involved information received action, perception, interpretation to a decision-making activity [2].

Medical personnel is responsible for patients. However, their activity also allows for stress. Stress on medical personnel influences works performance. Adverse physical and mental conditions affect their work. It influences the quality of services to patients. According to Colligan, et al. [3], commonly, error rates of medical personnel are in the

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intensive care unit (ICU), Radiation Oncology (RO), and emergency department (ED). Physiological and psychological factors make medical errors occur. Some causes included increased workload, fatigue, ineffective communication, and wrong information [4, 5]. The nurse is a work that requires productive activity and minor error [3, 6]. Changing of nurse mental workload affected patient health and safety [7, 8]. Some studies on mental workload in the health sector have been carried out, such as [Mazur, et al. [9], 10, 11], [Walters and Webb [12], 13, 14], and Liang, et al. [15]. However, in previous studies, the assessment of mental workload was carried out in one work unit. To our knowledge, there is no study to assess the mental workload for the complete hospital unit.

Ergonomics aims to increase the efficiency, health, safety, and comfort of humans in the workplace [16-18]. In ergonomics, the researcher can measure physical workload and mental workload. The relationship between mental workload and physical workload attracts the attention researcher. In some activities, physical and mental tasks increase the workload [19-21]. Mental workload is a factor that affects of performance of an activity. Some of these mental tasks required concentration, attention, memory, planning, and decision making [22]. Therefore, mental workload influences fatigue, and it increases operating errors [23]. It correlates with workplace factors and physical workload as one of the hazards [24, 25].

The mental workload and effects on the performance of physical workload toward worker must measure [22]. Therefore, this research aims to measure the mental workload and the physical workload of medical personnel. Physical workload evaluation is conducted with a percentage of % Heart Rate Reserve (HR Reserve) medical personnel [26-29]. It is done to determine the beats per minute based on the maximum pulse, work pulse, and resting pulse. The measurement of mental workload used the NASA-TLX method [30]. National Aeronautics and Space Administration Task Load Index (NASA-TLX) is a tool to assess individuals' workload. The NASA-TLX has a six-item. Initially, It used to measure workload in the laboratory, aviation. Furthermore, it has been applied to workload measurement in several sectors such as nuclear energy, transportation, and health care [30-35].

2. Methods

In this research, workload measurement is divided into 2. The first is the physical workload, and the second is the mental workload. The technique used is described as follows:

2.1 Measure physical Workload

The medical personnel's physical workload was measured using pulse rate. Heart rate is used to measure physical activity levels. Commonly, it is an average of beats per minute [28]. We measured the pulse of the worker before work. Furthermore, they take a rest for 30 minutes. The Karvonen Formula was used to measure the intensity of activity [36] (see Equation (1) and (2)). The Heart Rate Reserve (HR Reverse) expressed in percentage is formulated in Equation (3). Furthermore, there are five classifications in % HR Reverse. Less than 30% indicate no fatigue. 30% -60% describe the need for improvement. 60%-80% describe work in no time. 80%-100% describe urgent action is required. And, more than 100 describe no activity allowed.

$$Maximum\ heart\ rate\ = 220 - age \quad (1)$$

$$Heart\ rate\ reserve\ = Maximum\ heart\ rate - resting\ heart\ rate \quad (2)$$

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$$\%\ HR\ Reserve = \frac{Work\ heart\ rate - resting\ heart\ rate}{Maximum\ heart\ rate - resting\ heart\ rate} \quad (3)$$

In addition, we calculated the energy consumption of medical personnel activities. It is carried out to measure the level of activity. There is 5 level of activity such as Unduly Heavy, Very Heavy, Heavy, Moderate, Light, and Very Light. Formula energy consumption is shown in Equations (4) and (5). Equation (4) describes Energy consumption for certain activities. Equation (5) represents Energy expenditure during working time ($Kkal/minute$). KE describes Energy consumption for specific activities ($Kkal/minute$). Et show Energy expenditure during working time ($Kkal/minute$). Ei describes Energy expenditure during rest time ($Kkal/minute$).

$$KE = Et - Ei \quad (4)$$
$$Et = 1{,}80411 - 0{,}0229038\,(x) + 4{,}71733 * 10^{-4}\,(x)^2 \quad (5)$$

2.2 Mental Measure Workload by NASA-TLX Methods

NASA-TLX instruments were given to respondents after they complete activities. The researcher explains NASA-TLX Instruments to respondents. It is carried out to ensure appropriate answer respondents. The workload is measured using procedures developed by Hart and Staveland [30]. Table 1 describes the NASA-TLX Rating Scale and Definitions. NASA-TLX procedure is explained as follows: 1). Weighting: NASA-TLX questionnaire given to respondents contained paired questions. In the NASA TLX method, there are six indicators as Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Performance (P), Effort (EF), and Frustration (F). The questionnaire has a low to a high rating (0-5). In this section, respondents choose the dominant indicator that causes workload. 2). Provision Rating: In this section, the respondents are asked to rate the six mental workload indicators. The rating is given depending on the mental workload of the respondent. The score is between 0 to 100. In the mental load score, the weights and ratings for each multiplied indicator are then summed and divided by 15 (the number of pairwise comparisons). 3). Calculating the product's value: this value is obtained by multiplying the rating by the factor weight for each indicator. 4). Calculated Weight Workload (WWL): Sum all weighted workload of product. 5). Calculated WWL Score: Calculate the average weighted workload. 6). Score Interpretation :The score interpretation based on calculated WWL are low (0-9); medium (10-29); Rather high (30-49); High (50-79); very high (80-100).

Table 1. NASA-TLX Rating Scale and Definitions

Workload Component	Endpoints	Definitions
Mental demand (MD)	Low to high	The mental and perceptual activity required by a task
Physical demand (PD)	Low to high	The physical activity associated with a task
Temporal demand (TD)	Low to high	The time pressure associated with the rate or pace required
Effort (EFs)	Low to high	The mental and physical work required to perform the task at a certain level
Frustration (F)	Low to high	Refers to the continuum of stress and contentment associated with task completion
Performance (P)	Good to poor	The degree of success or satisfaction felt upon the performance or completion of a given task

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2.3 Data collecting

Respondents in this study were medical personnel with criteria 1.) Experienced working for more than one year. Therefore, they were personnel who know the level of difficulty of the work. 2). The medical staff was in the right, physically, and spiritually condition. The study was conducted on 15 units of medical personnel. Physical Workload and Mental Workload were assessed from July 2017 through August 2018 in Malang Indonesia hospital. The total number of respondents in this study was 15. Respondents in this research were five general practitioners, Head of Emergency Room Nursing, Head of Child Nursing, Head of Special Service Unit for Stroke Nursing, Head of ICU Nursing, Head of Class 1 Nursing, Head of Class 2 Nursing, Head of Class 3 Nursing, Head of VIP Class Nursing, Head of Childbirth Nursing and Head of Surgery Nursing.

2.4 Data analysis

We compared the Mental workload of the General Practitioner toward the Head of the Nurse. It was carried out using the independent sample t-test [37, 38]. We used Minitab version 14 to solve the independent sample t-test. We have hypotheses that there are mental workload differences between a general practitioner and head of nursing.

3. Result and Discussions

3.1 Physical workload measurement

Table 2 shows the Pulse Rate of Medical Personnel. Furthermore, Pulse Rate is used to measure energy consumption. The result of energy expenditure and the energy consumption is shown in Table 3. Overall, Energy Expenditure respondents ware category lightly. Although category light, activity in medical give concentration [22]. Therefore, Heart Rate Reserve show some respondent in Need improvement category (Table 4). They are General practitioner 1, Head of ICU Nursing, Head of Class 1 Nursing, Head of Class 2 Nursing, and Head of Surgery Nursing. Moreover, respondents were category no fatigue.

Table 2. Pulse Rate of Medical Personnel

Respondent	Age (years)	Pulse Rate (beat/minute)		
		Before Work	After Work	After Rest
General practitioner 1	35	74	103	67
General practitioner 2	39	78	97	85
General practitioner 3	37	79	94	83
General practitioner 4	35	78	90	80
General practitioner 5	35	79	96	85
Head of ER Nursing	35	80	100	90
Head of Child Nursing	35	83	104	94
Head of Stroke Nursing	42	79	94	84
Head of ICU Nursing	37	83	110	83
Head of Class 1 Nursing	35	79	99	76
Head of Class 2 Nursing	37	76	100	74
Head of Class 3 Nursing	40	76	102	80
Head of VIP Class Nursing	42	80	100	85
Head of Childbirth Nursing	43	83	101	80
Head of Surgery Nursing	40	79	104	78

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Table 3. Energy Expenditure

Respondent	Et	Ei	KE	Catagory
	After Work	After Rest		
General practitioner 1	4.4	2.4	2.1	Light
General practitioner 2	4.0	3.3	0.8	Light
General practitioner 3	3.8	3.1	0.7	Light
General practitioner 4	3.5	3.0	0.6	Light
General practitioner 5	3.9	3.3	0.7	Light
Head of ER Nursing	4.2	3.5	0.7	Light
Head of Child Nursing	4.5	3.8	0.7	Light
Head of Stroke Nursing	3.8	3.2	0.6	Light
Head of ICU Nursing	5.0	3.1	1.8	Light
Head of Class 1 Nursing	4.1	2.8	1.4	Light
Head of Class 2 Nursing	4.2	2.7	1.5	Light
Head of Class 3 Nursing	4.4	3.0	1.4	Light
Head of VIP Class Nursing	4.2	3.3	1.0	Light
Head of Childbirth Nursing	4.3	3.0	1.3	Light
Head of Surgery Nursing	4.5	2.9	1.6	Light

Table 4. Heart Rate Reserve (HR Reserve)

Respondent	HR after Work (beat/min)	HR after Rest (beat/min)	% of HR reserve	Catagory
General practitioner 1	103	67	30.50%	Need improvement
General practitioner 2	97	85	12.50%	No fatigue
General practitioner 3	94	83	11%	No fatigue
General practitioner 4	90	80	9.52%	No fatigue
General practitioner 5	96	85	11%	No fatigue
Head of ER Nursing	100	90	9.52%	No fatigue
Head of Child Nursing	104	94	14%	No fatigue
Head of Stroke Nursing	94	84	13.40%	No fatigue
Head of ICU Nursing	110	83	33.75%	Need improvement
Head of Class 1 Nursing	99	76	39.32%	Need improvement
Head of Class 2 Nursing	100	74	31.11%	Need improvement
Head of Class 3 Nursing	102	80	25.54%	No fatigue
Head of VIP Class Nursing	100	85	28.92%	No fatigue
Head of Childbirth Nursing	101	80	27.27%	No fatigue
Head of Surgery Nursing	104	78	31.70%	Need improvement

3.2 Mental workload measurement

Some data was collected to measure mental workload. These data included the Paired Comparison and the rating score. Table 5 shows the Paired Comparison of General Practitioner. Table 6 describes the head of nursing paired comparison data. Table 7 shows a rating score of a general practitioner. Table 8 describes the rating score of the head of nursing. Moreover, data were used to measure WWL and average WWL. Table 9 shows the result of WWL and WWL average from General Practitioner. Table 10 describes the Result of WWL and WWL average from the head of nursing. Furthermore, the classification of medical personnel based on Nasa TLX Analysis is shown in Table 11. NASA-TLX measurement results showed that mental workloads were categorized as

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complex and very hard. These results are from the research of Liang, et al. [15] and [Mazur, et al. [9], 10, 11]. Therefore, medical work poses a significant mental workload.

Table 5. Paired Comparison of General Practitioner

General Practitioner	Indicator						Total
	MD	PD	TD	P	F	EF	
Respondent 1	5	2	1	4	0	3	15
Respondent 2	3	3	0	5	1	3	15
Respondent 3	4	1	1	5	1	3	15
Respondent 4	4	2	1	5	0	3	15
Respondent 5	2	2	3	3	2	3	15

Table 6. Head of Nursing Paired Comparison

Head of Nursing	Indicator						Total
	MD	PD	TD	P	F	EF	
(ER) Emergency Room	2	3	2	4	0	4	15
Children Room	3	3	3	0	1	5	15
Stroke	3	4	1	4	0	3	15
ICU Room	2	4	4	2	0	3	15
Class 1 Room	4	2	3	3	0	3	15
Class 2 Room	3	3	2	3	2	2	15
Class 3 Room	2	4	3	1	0	5	15
VIP Room	3	2	1	4	0	5	15
Childbirth Room	3	2	3	2	0	5	15
Surgery Room	3	2	5	2	0	3	15

Table 7. Rating Score of General Practitioner

General Practitioner	Indicator					
	MD	PD	TD	P	F	EF
Respondent 1	90	90	80	80	30	90
Respondent 2	60	70	70	80	70	70
Respondent 3	50	50	50	70	70	70
Respondent 4	50	50	50	70	70	70
Respondent 5	70	70	70	70	70	70

Table 8. Rating Score of Head of Nursing

Head of Nursing	Indicator					
	MD	PD	TD	P	F	EF
(ER) Emergency Room	20	70	70	90	20	90
Children Room	70	60	60	90	50	90
Stroke	50	60	60	70	50	70
ICU Room	90	100	90	100	20	90
Class 1 Room	80	60	90	90	70	90
Class 2 Room	90	90	80	90	60	90
Class 3 Room	90	90	80	80	70	80
VIP Room	80	80	80	100	30	100
Childbirth Room	80	80	90	80	70	90
Surgery Room	70	100	90	90	80	90

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Table 9. Result of WWL and WWL average from General Practitioner

General Practitioner	Indicator						WWL	WWL Average
	MD	PD	TD	P	F	EF		
respondent 1	450	180	80	320	0	270	1300	87
respondent 2	180	210	0	400	70	210	1070	71
respondent 3	200	50	50	350	70	210	930	62
respondent 4	200	100	50	350	0	210	910	61
respondent 5	140	140	210	210	140	210	1050	70

Table 10. Result of WWL and WWL average from Head of Nursing

Head of Nursing	Indicator						WWL	WWL Average
	MD	PD	TD	P	F	EF		
Emergency Room (ER)	40	210	140	360	0	360	1110	74
Children Room	210	180	180	0	50	450	1070	71
Head of Stroke	150	240	60	280	0	210	940	63
ICU Room	180	400	360	200	0	270	1410	94
Class 1 Room	320	120	270	270	0	270	1250	83
Class 2 Room	270	270	160	270	120	180	1270	85
Class 3 Room	180	360	240	80	0	400	1260	84
VIP Room	240	160	80	400	0	500	1380	92
Childbirth Room	240	160	270	160	0	450	1280	85
Surgery Room	210	200	450	180	0	270	1310	87

Table 11. The Classification of Medical Personnel Based on NASA TLX Analysis

Respondent	Mental Workload Value	Category
General practitioner 1	87	Very high
General practitioner 2	71	High
General practitioner 3	62	High
General practitioner 4	61	High
General practitioner 5	70	High
Head of ER Nursing	74	High
Head of Child Nursing	71	High
Head of Stroke Nursing	63	High
Head of ICU Nursing	94	Very high
Head of Class 1 Nursing	83	Very high
Head of Class 2 Nursing	85	Very high
Head of Class 3 Nursing	84	Very high
Head of VIP Class Nursing	92	Very high
Head of Childbirth Nursing	85	Very high
Head of Surgery Nursing	87	Very high

Table 12. Independent sample t-test of the mental workload

	General practitioner	Head of Nursing	df	t value	t-table
Std Deviasion	86,94	83,76	8	-2.140	2.306
Rata-rata	81,8	70,2			
Respondent	5	10			

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The result of compare means independent sample t-test is t count < t table (Table 12). Therefore, the initial hypothesis is accepted. The mental workload of general practitioners is different from the head of nursing. This study shows that the mental workload of nurses in the ICU is higher than the other units. However, the value of % HR reserve in the head of the nurse in class 1 has the highest amount compared to the unit other. The results of this study harmonized by Mazur, et al. [34]. Tubbs-Cooley, et al. [35] also found high correlations with the mental workload in ICU nurses. It is also proved that research Hoonakker, et al. [39] and Colligan, et al. [3]. Therefore NASA TLX is a helpful tool to measure mental workload [40]. NASA-TLX is helpful to measure the mental workload of medical personnel. Although the results obtained in previous studies vary, it is caused by various factors. Some factors included such as the practical design of work, resources available, a culture of teamwork and collaboration, and employee prosperity [7, 41].

4. Conclusion

The measurement results of physical workload medical personnel are a mild category. However, for mental workload measurement, The General practitioner's mental workload is category high. Furthermore, heads of nursing were classified in a very high grade. In mental and physical workload, nurses produced the highest score. They always are alert and responsive in helping patients. Hence, the workload in ICU nurses highest. Some that activity is encouraging, attracting, controlling, and operating medical devices. In addition, The highest physical workload is in nurses class 1. In this class 1, the head of nursing must focus on helping patients, and they always fast in helping patients. Moreover, they are required to still work quickly to helped patients properly. For future work, we suggestions for the next researcher. Some future research included investigating the physical and mental workload in another field such as Pharmacy and front officer in hospital. Furthermore, the future researcher can use another method, the physical and mental workload.

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Please cite this article as: Restuputri, D., Pangesti, A., & Garside, A. (2019). The Measurement of Physical Workload and Mental Workload Level of Medical Personnel. Jurnal Teknik Industri, 20(1), 34-44.. doi:https://doi.org/10.22219/JTIUMM.Vol20.No1.34-44

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